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THE LARGER RESULTS OF 20 YEARS OF SOLAR RADIATION OBSERVATIONS

BY C. G. ABBOT, F. E. FOWLE AND L. B. ALDRICH

ASTROPHYSICAL OBSERVATORY, SMITHSONIAN INSTITUTION, WASHINTON

Read before the Academy, April 24, 1922

In Volume 4 of the *Annals of the Astrophysical Observatory* are given the results obtained from 1912 to 1920, but the discussions go back to the beginning of the investigations of solar radiation at the Smithsonian Institution in 1902. Where so many details are taken up it is a little hard to keep in mind the broad outlines, and we propose to give a general view of the work in what follows.

We measure the solar heat received by the earth; determine the limits of its variability; study the distribution of solar radiation in the spectrum, and its intensity over the solar disk; and we investigate the properties of the terrestrial atmosphere in relation to the passage of solar rays to the earth's surface and the escape of earth rays to space.

When the work was begun in 1902, great diversity of results prevailed. The black bulb in vacuo thermometer, Pouillet's pyrheliometer, Tyndall's, Violle's and Crova's actinometers, and the older form of Ångström's compensation pyrheliometer, differed through a range of at least 50 per cent in their indications. Values of the "solar constant" or intensity of solar radiation outside our atmosphere at mean solar distance ranged from 1.76 to 4.0 calories as given in the best text-books. Nothing was known as to the limits of the solar variability.

1. *Standardization and perfecting of methods and apparatus.*—While the methods we have used are Langley's they have been reduced to a finished system of every day procedure. The theory, practice, sources of error and details needful to accurate results in solar constant observing have been worked out and published in Volumes 2, 3, and 4 of the *Annals of the Astrophysical Observatory.*

Two forms of standard pyrheliometer have been devised, perfected and used to establish the scale of solar radiation measurement. Both types of instrument have hollow chamber or "black body" receivers of radiation, and in both test quantities of electrically introduced heat have been measured with close agreement.

A secondary instrument, called the silver-disk pyrheliometer, has also been perfected. About 30 standardized copies have been purchased by observers in many countries of the world. Thus the standard scale of radiation has been widely diffused. Our measurements are approximately 2 per cent higher than those of the system of Ångström with its latest corrections.

Among other instruments developed or improved for the work are the 2-mirror coelostat; the reflecting galvanometer; the vacuum bolometer for which a full mathematical theory was derived; the pyranometer, an instrument for measuring the radiation received from the daylight sky; the honeycomb pyranometer or melikeron, a "black-body" instrument for observing nocturnal radiation; the ballon pyrheliometer, 5 copies of which attached to sounding balloons, were raised to great altitudes in 1913 and 1914 for observing the solar radiation very high up in the atmosphere; the slide wire extrapolator and special plate measuring instrument, both used for the reduction of observations of the solar constant of radiation.

2. *Value of the Solar Constant.*—About 2000 observations of the intensity of solar radiation outside the atmosphere at mean solar distance, otherwise called the "solar constant," have been made according to the high and low sun method of Langley as systematized and perfected by use. These measurements have been made at Washington (sea level); Bassour, Algeria (1,160 meters); Hump Mountain, North Carolina (1,500 meters); Mt. Harqua Hala, Arizona (1,729 meters); Mt. Wilson, California (1,735 meters); Calama, Chile (2,250 meters); Montezuma, Chile (2,900 meters?); and Mt. Whitney, California (4,420 meters). The circumstances of observation have been widely varied, ranging from days of high humidity in summer at Washington to less than a millimeter of precipitable water as in the atmosphere above Mt. Whitney; at temperatures from those of the Sahara Desert in Algeria to −25° C. at Hump Mountain, North Carolina; and clearness of the atmosphere, from the deep blue which prevails right up to the sun's disk on Mt. Whitney and Mt. Montezuma down to the white dusty sky which prevailed in the year 1912 at Mt. Wilson and in Algeria after the eruption of the volcano Mt. Katmai in Alaska.

These varied circumstances appear to produce very little influence on the solar constant results, and the mean value, 1.94 calories per square centimeter per minute, is closely confirmed by the observations of the balloon pyrheliometer raised to an elevation of nearly 25,000 meters where the atmospheric pressure is reduced to one twenty-fifth of its value at sea level.

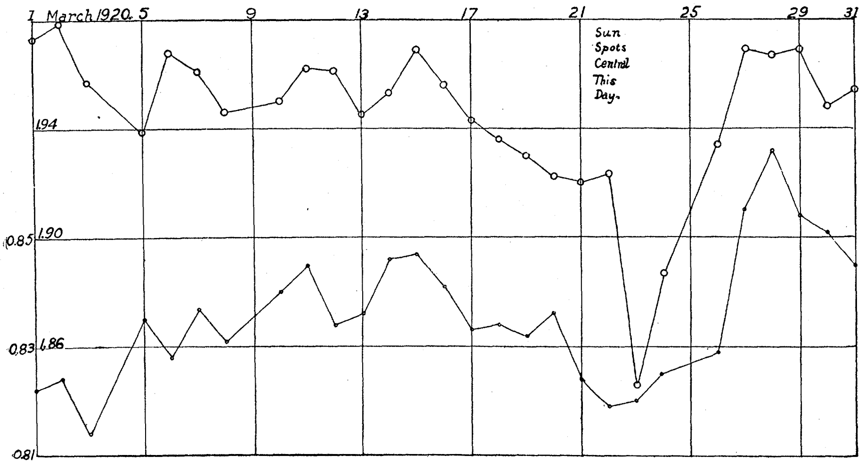
We believe this value, 1.94 calories per square centimeter per minute, may be regarded as the datum mark for this epoch with which may be compared in future centuries the solar radiation at that time prevailing in order to determine what, if any, secular changes of it have occurred.

3. *Solar Variation.*—To state the negative first, our observations have shown that the sun is not, like some of the other stars, widely variable but has at any rate not been found to vary in excess of 12 per cent in the last 20 years. In general its variations do not exceed 5 per cent in a month.

On the other hand, solar variations of from 1 to 5 per cent appear to occur at irregular intervals and with irregular magnitudes of variation;

the observed range often reaches 2 per cent within a period of ten days, and not infrequently, as, for instance at the time of the great central sun-spot group of March 22, 1920, a change of 5 per cent within 10 days is noted. The extreme range of values which has been observed by us since 1902 is approximately 12 per cent.

Long period solar variation attending the changes of solar activity, as evidenced by sun-spots, prominences, and other visible solar phenomena, appears to reach about 3 per cent for 100 Wolf sun-spot numbers. Higher solar radiation prevails at times of higher solar activity.



Solar constant and atmospheric transmission affected by great central sun-spot group, March, 1920.

Lower curve, atmospheric transparency wave-length 0.511 microns, Calama, Chile.

If *depression* of atmospheric transmission were erroneous, the result would be *increase* of solar-constant values. Apparently bombardments of earth by solar ions attending central passage of sun-spot group diminish transparency of the earth's atmosphere. This effect is frequently noted.

4. *Confirmatory Evidences of Solar Variation.*—(*a*) By studies of the distribution of radiation in the telescopic image of the sun's visible disk, fluctuations of the contrast of brightness between the center and edge of the sun have been observed for many wave-lengths. These fluctuations have complex correlation with the observed variations of the solar constant of radiation.

(*b*) In the distribution of radiation in the solar spectrum outside the atmosphere, high values appear at the shorter wave-lengths, as compared with the longer ones, when the solar radiation values are high.

(*c*) Solar radiation values themselves have been carried on at stations many thousands of miles apart and have checked one another in their indications of solar variability.

(*d*) From a rather small number of observations by Guthnick on the brightness of the planet Saturn, it appears that equal fluctuations of the brightness of the planet attend observed fluctuations of the radiation of the sun. This result, however, requires that allowance shall be made for the rotation of the sun to take into account the difference in heliographic longitude between the earth and Saturn.

(*e*) Various observers, notably Clayton, Arctowsky, Helland-Hansen, and Nansen, have published results showing the correlation between terrestrial temperatures, and other meteorological phenomena, and our observed variations of the sun.

(*f*) Bauer found a correlation between solar variation and the variations of terrestrial magnetism.

5. *Atmospheric Transparency.*—We have determined the transparency of the earth's atmosphere to solar radiation at stations ranging from sea-level to 4,420 meters for nearly 40 wave-lengths. We have observed the dependence of the atmospheric transparency on humidity and volcanic dust, and its variation from month to month, and from year to year. Since atmospheric transparency is associated, by Rayleigh's theory of the blue of the sky, with the number of molecules per cubic centimeter of air, our results have led to an independent value of this constant for which Mr. Fowle finds 2.70×10^{19} molecules per centimeter cube in air at standard temperature and pressure.

6. *Brightness of the Sky.*—Measurements have been made of the brightness of the sky by day, as a whole and in parts, and the variation of it from sea-level to 4,420 meters, as well as the effects upon it of the presence of clouds.

Mr. Aldrich took advantage of the presence of the Balloon School at Arcadia, near Mt. Wilson, to observe the reflecting power of clouds as formed there in a great level sheet some 500 meters high. From his results, it appears that if the earth were completely enshrouded in a smooth layer of cloud its reflection would be approximately 77 per cent.

7. *Long-wave Ray Investigations.*—Mr. Fowle carried on spectrobolometric investigations of the rays of the Nernst glower as affected by the humidity and carbon dioxide prevailing, in very long absorbing tubes at atmospheric pressure and temperature. These measurements covered the spectrum in the region of the earth's emission up to a wave-length of nearly 20 microns. The investigation included the distribution of the rays in the solar spectrum in this region. Many measurements have been made also on the absorption and reflection of liquid water, and many other terrestrial substances and of their degree of transparency to long-wave rays.

9. *Distribution of Radiation over the Sun's Disk.*—It was previously known that the brightness of the sun's disk falls off towards the edges, but

these measurements have been made in detail for many different wave-lengths and with the very high degree of precision necessary to observe the fluctuations of contrast of brightness from time to time. The measurements extended beyond the visible spectrum both towards the ultra-violet and towards the infra-red, and showed a striking change of distribution along the sun's diameter, depending on the difference of wave-length.

10. *Solar Theory.*—These solar radiation measurements, including those of the solar constant which have led to a value of the sun's effective temperature, those on the distribution of light over the sun's disk, and those on the transmission of the terrestrial atmosphere considered in conjunction with the known results of others on the details of the solar spectrum, have led to a theory of the sharp boundary of the sun and other things relating thereto which appears more and more to gain acceptance.

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*REPLANTATION OF ENTIRE LIMBS WITHOUT SUTURE OF VESSELS**

By William S. Halsted

Medical School, Johns Hopkins University

Read before the Academy, April 24, 1922

The experiments were undertaken with view to determining the amount and duration of the swelling which would result from the division of all the vessels and lymphatics of a limb, our interest in the subject arising from the desire to obtain experimental support of my contention that permanent swelling of the arm following operations upon the axilla is probably invariably due to infection, an infection often so slight as to escape the observation of the surgeon. It is almost a daily experience of active surgeons to see swollen arms as result of radical operations for cancer of the breast. The swelling is frequently so great as to cause suffering and disability from the weight of the arm, and occasionally patients have consented to amputation of the entire limb for the condition which surgeons have been powerless to relieve. The ordinary swelling is universally attributed to the removal of the axillary lymphatics and veins, and some surgeons have advocated operations less thorough, believing that their results as regards the swelling of the arm have been better when the axilla was less meticulously cleaned.

Almost from the beginning of our radical operations for cancer of the breast I have been impressed with the fact that infection, however slight, was likely to be followed by more pronounced swelling of the arm and that the largest arms were noted as a rule in cases in which the inflammatory reaction and the axillary induration were greatest. We assumed, naturally,